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SOME ORIGINAL OBSERVATIONS ON RESPIRATORY- PULSE CURVES AND VENOUS PULSE IN HEALTHY PEOPLE.

BY LIEUTENANT-COLONEL H. E. DEANE.

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THESE observations are the outcome of a paper I presented at the Annual Congress of Preventive Medicine in 1905, and published in May and June, 1906, on the "Causation and Prevention of the Irritable Heart of Soldiers." In that paper I referred to the increase of pulse-rate after a recruit's gymnastics, both free gymnastics and apparatus work. I realised that I wanted a standard for a comparison, and looked for one in various text-books on physiology. I found none.

I collected many observations of both sexes after such games as hockey and football, and after gymnastic exercises of various kinds. The tracings given to illustrate this paper were taken, except when otherwise stated, from non-commissioned officers undergoing training at the Aldershot gymnasium, which I have been able to do by the courtesy and help of Colonel S. P. Rolt, Inspector of Gymnasia. The observations led to others, which appear important, and which, I think, show that the effect of respiration on the circulation is not yet settled; and the observations have an important bearing on the stress now being laid on deep-breathing and so-called breathing exercises during gymnastic work. For reference I give quotations from Schäfer's "Text-book of Physiology," dealing with the influence of respiration on the pulse.

"The frequency of the heart is increased by inspiration by a lessening of the vagal tone."

"Diastole of heart favoured by inspiration."

"Systole of heart favoured by expiration."

"Frequency of heart increased by inspiration."

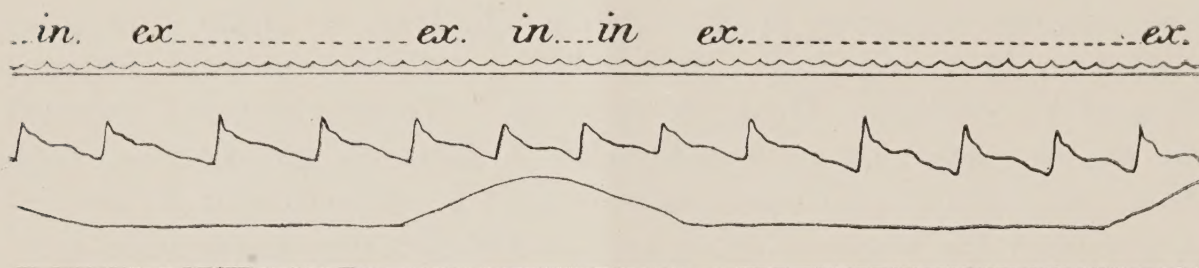
"Frequency of heart lessened by expiration."

I have taken many simultaneous records of respiratory and pulse curves during the last two years, by means of Mackenzie's polygraph, on people leading an ordinary quiet life, on athletes, on trained gymnasts, and men undergoing gymnastic training, and on professionals, and I take for consideration, first, natural quiet respiration, giving samples of the tracings.

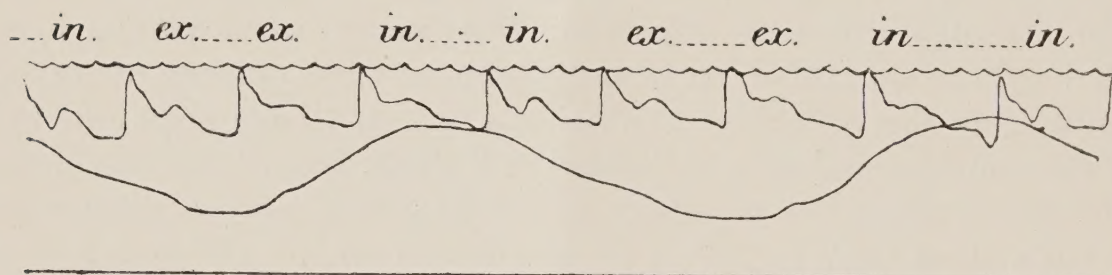
Quiet Respiration.—The quickening of the pulse during inspira-

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tion and slowing during expiration, as laid down in the books, are not confined to the respective phases of the respiratory act. Take the slowing as a starting point. It does not always begin immediately on expiration, there being very often one or two beats the same length, or even shorter than the preceding inspiratory beat; then the expiratory diastoles lengthen, sometimes progressively to the end of expiration, though at other times the last expiratory diastole is shorter than the preceding ones.



TRACING NO. 1.



TRACING NO. 2.

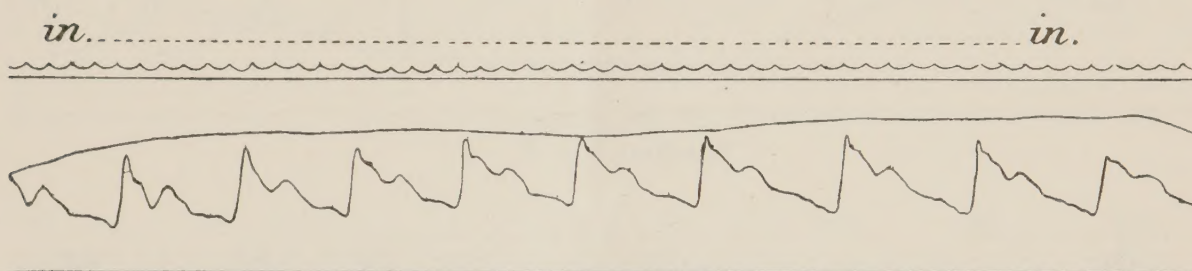
Sometimes, when marked slowing has begun suddenly on expiration, the succeeding diastoles become progressively shorter during the expiration and the following inspiration, and then the diastoles lengthen again (Tracing 1). Sometimes the first diastole of an inspiration is more prolonged than the preceding expiratory one (Tracing 2), as though the influence causing the lengthening were continued into the next inspiration.

Men in the best physical condition for effort and endurance, as George Hackenschmidt, the champion wrestler of the world, Tom Burrows, the champion club swinger of the world, whose tracings I have, show, in some cases, very slight respiratory pulse variations, in others the changes are very marked. Unfortunately, the length of the tracings are inconvenient for insertion in a journal.

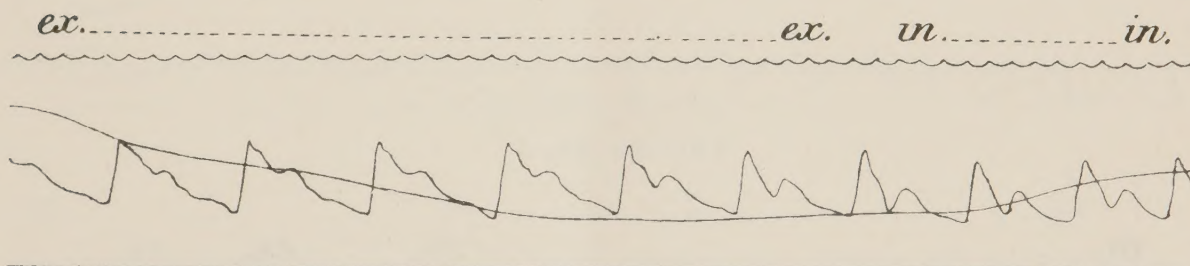
Deep Breathing.—Again, for reference, I quote from Schäfer's "Physiology": "The respiration is deep, the inspiratory movement is

executed more rapidly than the expiratory, and the periodicity is such that several heart-beats occur during each complete act of respiration. The heart-beat increases in frequency during inspiration."

I must first of all say that the deep breaths recorded on these tracings were drawn easily without any straining or effort whatever, nor was the breath held at all. I gave no directions except that no part of the body was to be moved in the slightest degree beyond the parts concerned in the breathing. The tracings were taken with the men sitting easily, and the arm to which the polygraph was attached on a level with the heart as near as possible.



TRACING No. 3.



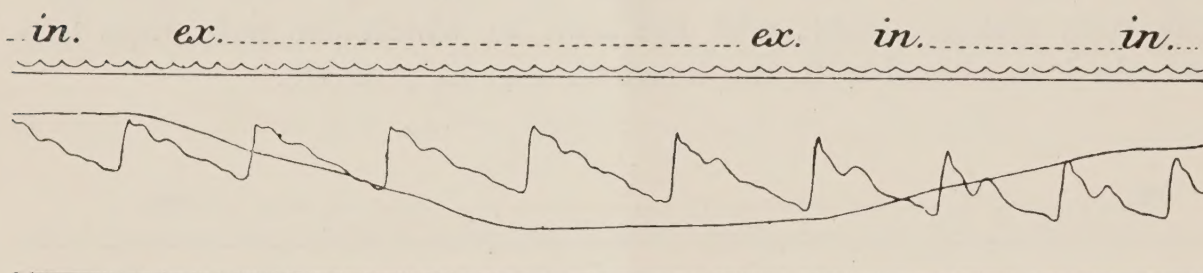
TRACING No. 4.

Until quite lately I had found some peculiar effects on the pulses during deep breathing only in men undergoing gymnastic training, but I have recently observed the same things in a youth of 17, at Charterhouse School, where there is no organised physical training apart from games. In this case the diastoles at the end of inspiration are much prolonged, the first inspiratory diastoles being equal to the preceding expiratory one; then follow two or three shortened ones, to be followed by the above-mentioned lengthened ones, which are continued into the following expiration, though not maintained throughout the expiration, quickening again beginning before inspiration sets in (Tracings 3, 4). This is not invariable, at times the lengthening persisting through expiration

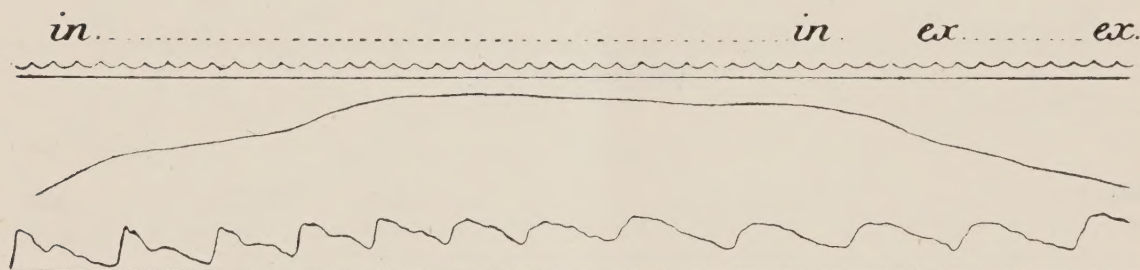
4 *Original Observations on Respiratory-Pulse Curves*

(Tracing 5). During some inspirations the pulse becomes markedly dicrotic. At other times the upstroke of the tidal wave is much shortened and presents a flattened plateau, the whole tidal wave being sometimes represented simply by a curve, and this curve may be continued into the succeeding expiration (Tracing 6).

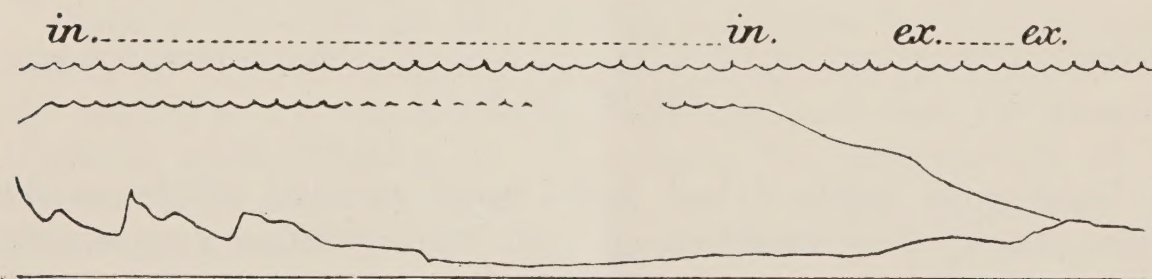
A frequent occurrence is complete stoppage of the pulse on deep inspiration. This occurs without any previous marked diastolic lengthening, and there are three or four beats of diminishing



TRACING NO. 5.



TRACING NO. 6.



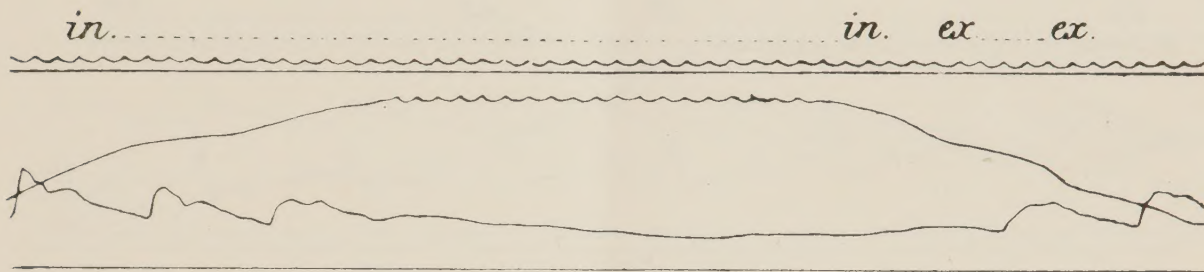
TRACING NO. 7.

amplitude before the stoppage occurs. The stoppage may continue into the succeeding expiration, and the return to normal is more or less sudden and complete, one, or perhaps two, diminished beats occurring before the return of the full pulse (Tracings 7, 8).

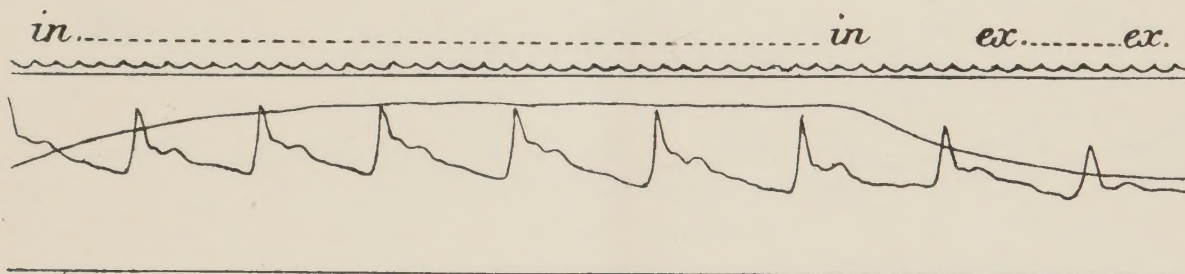
A quickening of the pulse at the beginning of a deep inspiration and a marked slowing towards the end, which slowing continues into the following expiration, then a gradual quickening again before

the expiration is completed, is a very common thing. The following tracings are samples (Tracings 9, 10, 11).

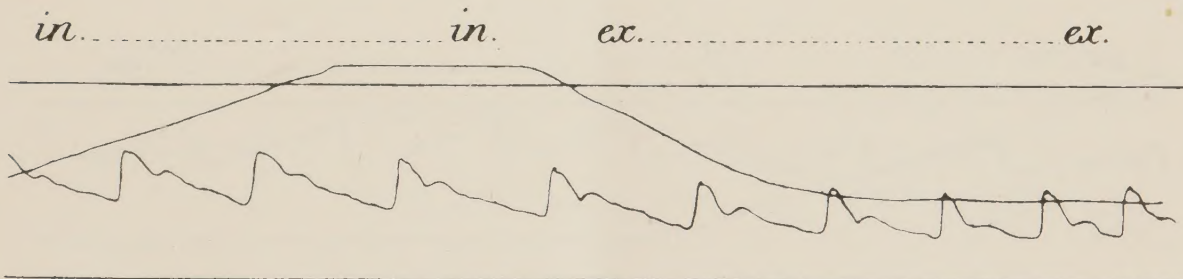
Sometimes the greatest diastolic lengthening occurs in the middle of the deep inspiration, the quickening occurring during the early part of the following expiration, then lengthening out again in the latter part of the expiration (Tracings 12, 13). The same man presented the same respiratory diastolic lengthening when he made



TRACING No. 8.



TRACING No. 9.



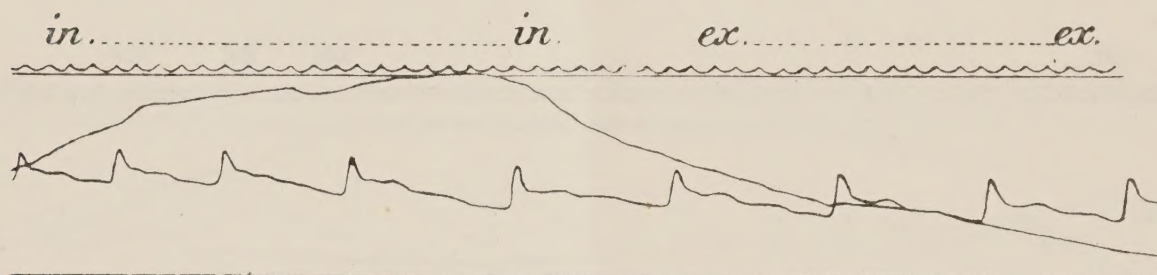
TRACING No. 10.

deep, quick inspirations and prolonged expirations, the expiratory diastoles diminishing, the first following inspiratory one being still smaller, to be followed by a greatly lengthened one (Tracing 14).

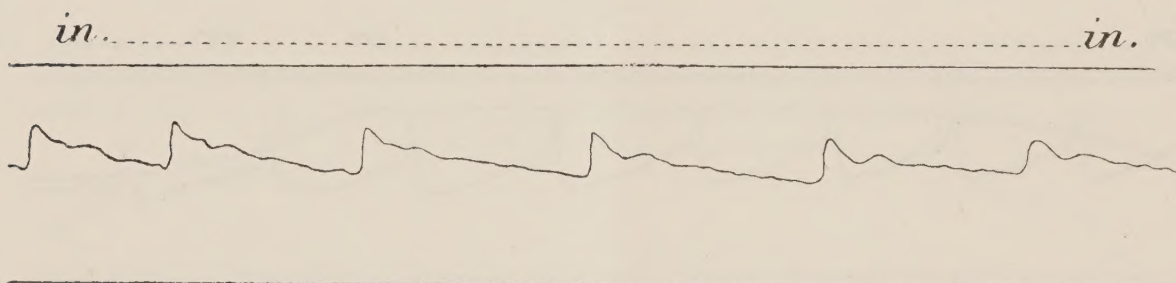
In one man in whom a stoppage of the pulse occurred during a deep inspiration, which was continued into the next expiration, a stoppage occurred during a few natural quiet inspirations following the deep one, and on continuing quiet respiration the pulse resumed its usual characters.

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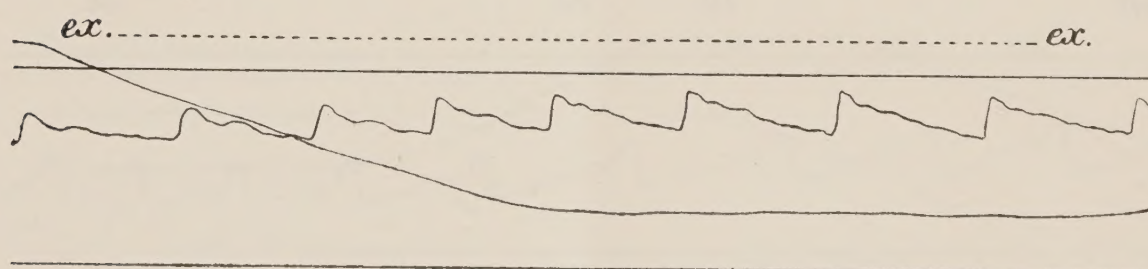
I have found this pulsus paradoxus common in soldiers undergoing training for gymnastic instructors, but, with the exception of the youth mentioned earlier in this paper, I have not yet met with it otherwise, but I have not yet made observations on a sufficient number of professionals to say what happens in their case. As graphic records will be worth more than mere description I give



TRACING NO. 11.



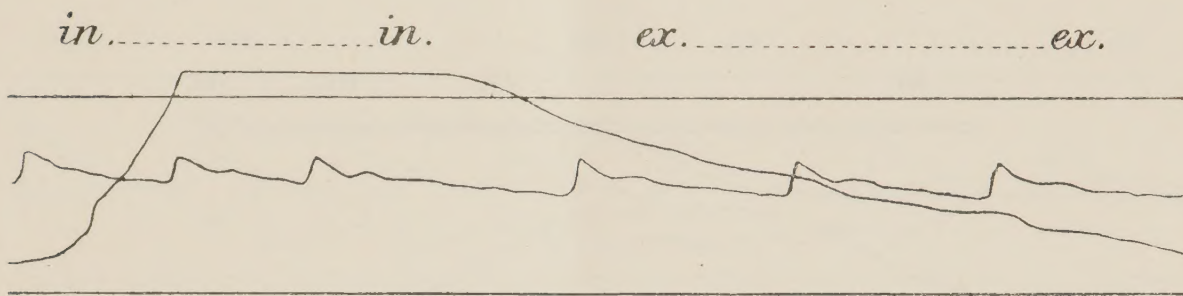
TRACING NO. 12.



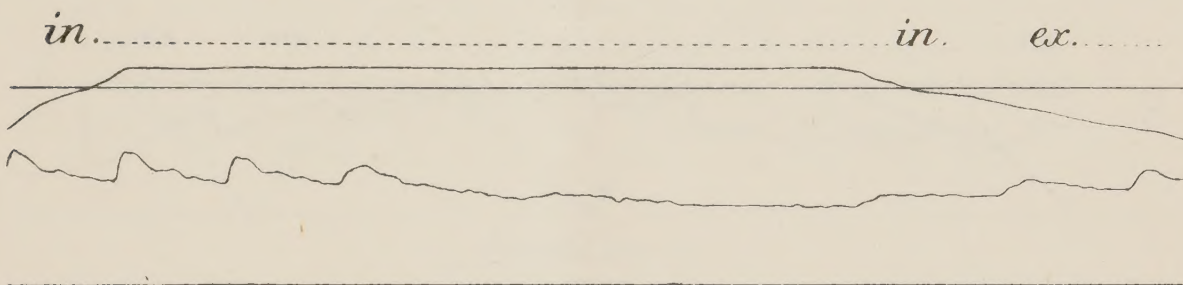
TRACING NO. 13.

a selection of my tracings (Tracings 15, 16, 17, 18). There is a point requiring further observation and which I shall investigate as opportunity occurs, and that is, the effect of posture. In the case of a man who almost constantly presented a pulsus paradoxus on deep breathing, I was unable to obtain it when he was lying down on the few occasions on which I tried, but it did occur in the standing position.

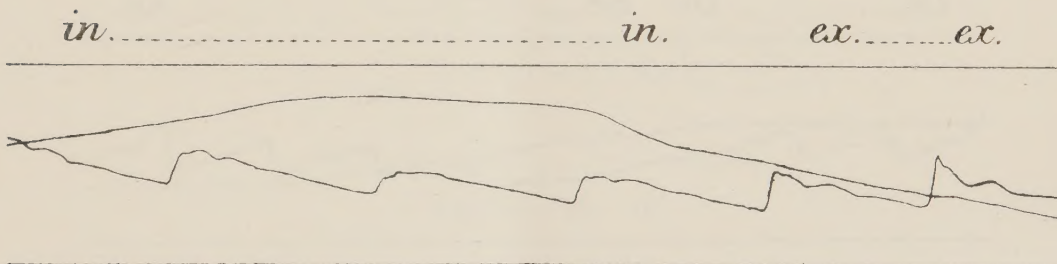
Referring to the quotations given previously from Schäfer's "Physiology" as to inspiration favouring diastole, does not that mean that the pulse would slow if inspiration were prolonged? If so, why is it said that inspiration quickens the pulse? Again, if the inspiratory quickening and expiratory slowing are due to vagal influence, why is the action reversed during deep breathing? It



TRACING No. 14.



TRACING No. 15.



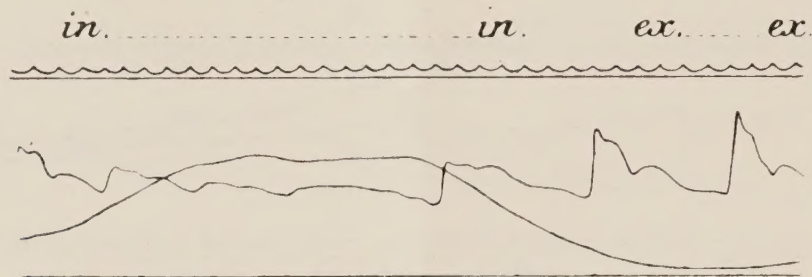
TRACING No. 16.

seems to me that these respiratory changes in the pulse may be due to varying quantities of blood in the heart, and that, if directly due to mechanical influence, such influence when started is continued for a time more or less irrespective of individual respiratory phases.

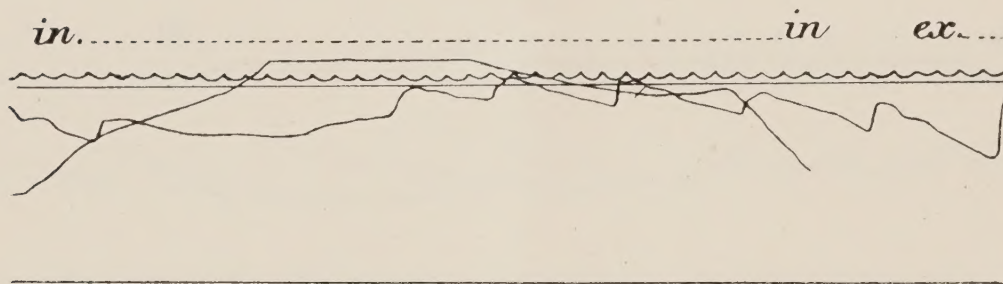
During the stoppage of the pulse the heart is beating regularly, but I am unable to give any graphic records of the fact. I have auscultated the heart with my finger on the pulse during the deep

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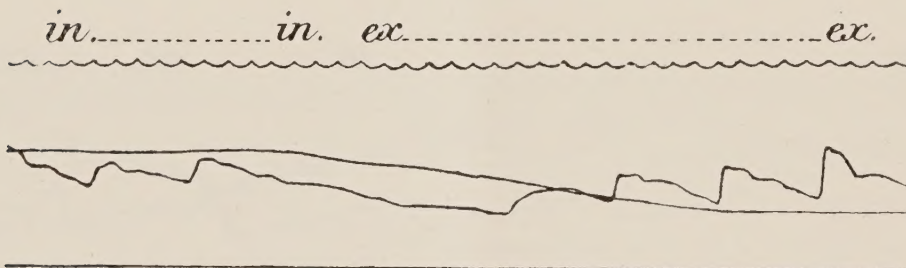
inspiration, and beyond the sounds being somewhat muffled by the expanding lung, I could find no change in the heart's action, which was not at all rapid nor markedly slowed. None of the many cases which I have observed showed any change in appearance, nor experienced any change of sensation, in fact, were perfectly unconscious of anything happening. The references in literature to the pulsus paradoxus are practically confined to morbid states or adherent



TRACING No. 17.



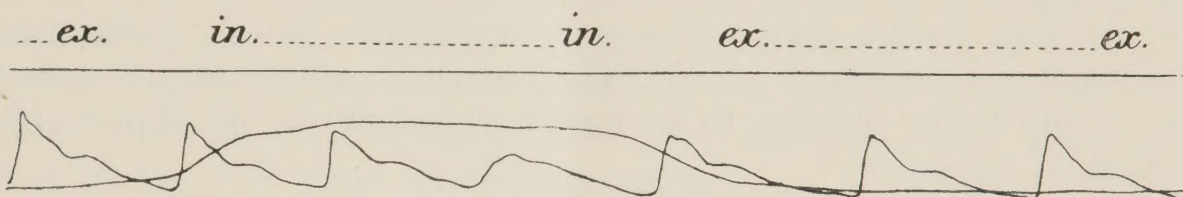
TRACING No. 18.



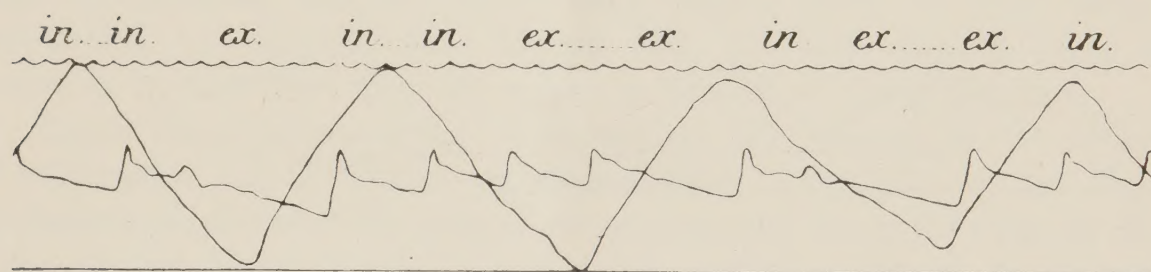
TRACING No. 19.

mediastinitis, the only exception I have met with being a tracing in Mackenzie's book on the pulse taken from a healthy man, and which he says he was unable to explain. The fact of the pulse stopping at the wrist, and of the heart-beats still continuing during that time, shows that not enough blood is being discharged from the left ventricle to reach the radial artery. What has happened to prevent it? The most feasible explanation is that the blood is being soaked up, as it were, by the lungs, and is not escaping

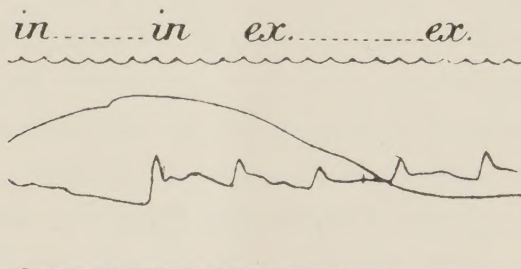
therefrom to the left side of the heart. Yet we see it stated in books that deep breathing assists the circulation of the blood from the right side of the heart to the lungs, through the lungs, and on to the left side of the heart. Is this stoppage of the pulse during a deep inspiration assisting the circulation, continuing as it does often into the following expiration? Deep breathing interspersed between exercises is supposed to quiet and equalise the circulation.



TRACING No. 20.



TRACING No. 21.



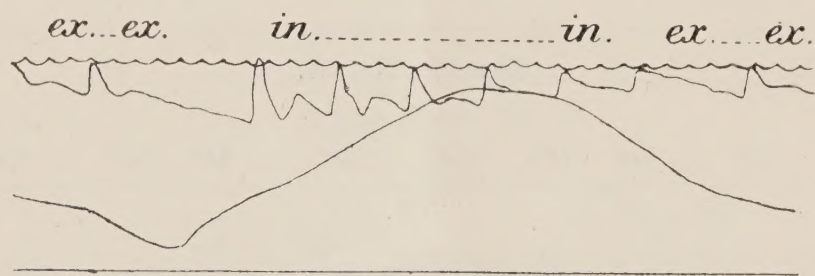
TRACING No. 22.

My observations tend to show the opposite. During deep breathing the respiratory rhythm is altered, inspiration being longer than expiration, and I am aware of no circumstances under which natural reflex breathing, so to speak, presents that character; a long, slow breath is an artificial proceeding performed by volition, whereas, when Nature requires a deeper breath it is drawn quickly, more in the nature of a long gasp, and, moreover, is not repeated immediately. So far as my observations have gone at present I am forced to the conclusion that deep breathing between exercises as advised and practised is unnecessary for any beneficial effect on the

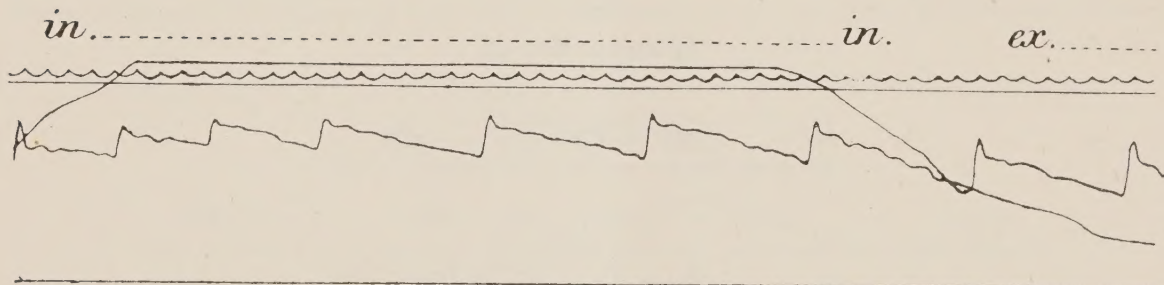
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circulation, and that it upsets the circulatory equilibrium with no obvious purpose. This leads me to the next series of observations I have made on the respiratory-pulse curves after the pulse has been quickened by such active exercise as running, both in untrained subjects and athletes.

After Quickening by Running.—During the panting period immediately succeeding the running the respiratory changes in the pulse are less marked; but as the respirations settle down, the shortening during inspiration and lengthening during expiration becomes more marked. When the breath is sufficiently recovered to enable deeper breaths to be drawn there may be no appreciable effect on the pulse.



TRACING No. 23.



TRACING No. 24.

Space does not admit of sufficient lengths of the tracings to be shown, but one or two examples of a special kind are given. An officer in the gymnastic class showed a pulsus paradoxus when drawing deep breaths after a run, at one time the stoppage occurring at the end of inspiration and continuing for about the first half of the following expiration (Tracing 19). This disturbance is shown in a less degree in Tracing 20, a case of a medical student, in which the alteration of inspiratory beats is marked when breathing deep after a run. During natural breathing no such change occurred. Sometimes the diastolic lengthening during the natural panting breathing after a run is very marked, as in Tracing 21, in which it occurs during expiration and attended by an

extra systole. This only occurred in the part of the tracing taken immediately after the run. During deeper breathing after running much prolonged diastoles may occur during inspiration or expiration, as in Tracings 22 and 23 from the same man. When deeper breaths can be drawn after a run a prolonged diastole may occur during either inspiration or expiration, in either case the following beats being more rapid. Again, when breathing more deeply after a run, which in this case was not fast (Tracing 24), marked diastolic lengthening occurs after a shortening during inspiration, the lengthening becoming gradually less in the following expiration; when the natural breathing was not interfered with diastolic lengthening took place during expirations.

All these tracings were taken in the sitting posture, and the men were taken from their gymnastic classes, and the tendency of the deep breaths drawn was to increase the pulse rate, in addition to altering the rhythm. If a man's pulse is very much quickened by exercise the easiest and quickest way to slow it down is to rest the man in either a sitting or lying position.

These observations seem to show that the subject of the effect of respiration on the pulse requires further investigation, and that explanations given of the *pulsus paradoxus* require modifying, in the light of the illustrations I have given having occurred in strong, healthy men.

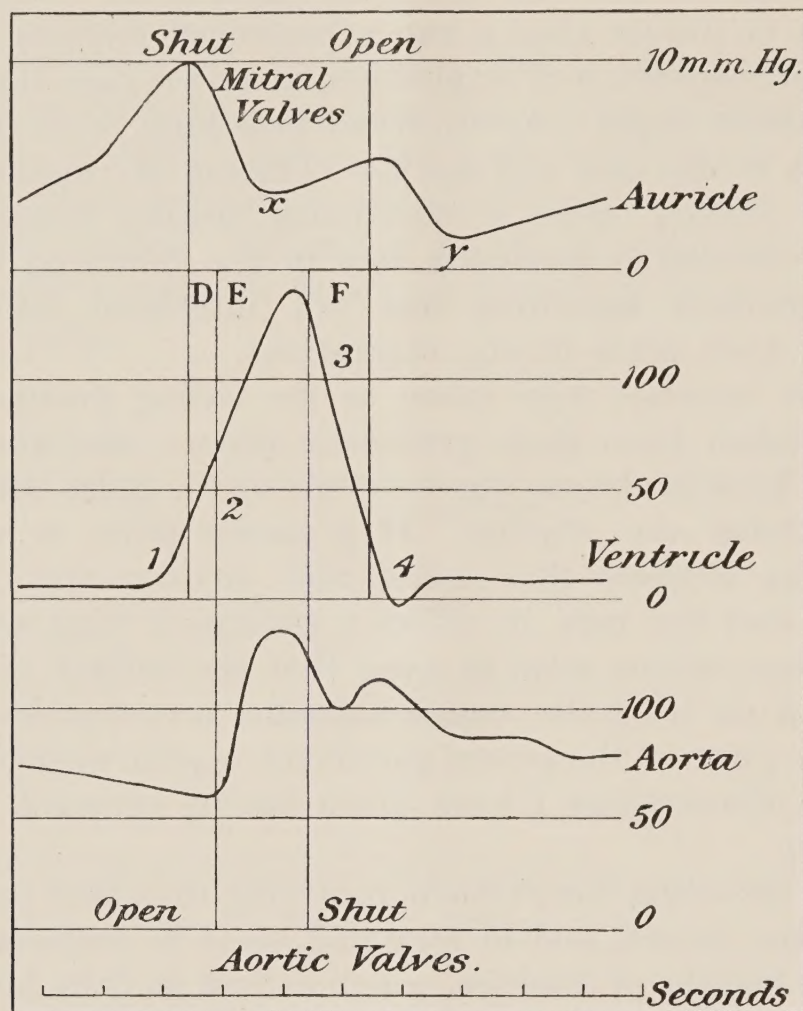
I DEFER recording observations regarding the effect on the pulse of holding the breath, and of straining, as it is necessary to show considerable lengths of tracings, which cannot be done here.

During my observations on a non-commissioned officer of the Gymnastic Class at Aldershot, who frequently exhibited a *pulsus paradoxus* and whose tracing has been already given, I found he had a venous pulse in the right jugular vein. I then tried his comrades in the same squad, and found they had it too, and on continuing the observations I found it an exceptional thing not to get one. I then extended my observations further afield, and in this paper I give illustrations of the results.

References to a venous pulse in the normal individual in text-books on physiology are either absent or very meagre, and also in text-books on clinical medicine, and in none of them is any explanation or analysis of the pulse curve given. A full analysis of the venous pulse and its variations is given by Dr. James Mackenzie in his "*Study of the Pulse*," and by his kind permission I reproduce the diagram of a cardiac cycle from the book and his description thereof, in order to make the explanation of the venous-pulse curve

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clear. I may say that all the tracings were taken from the right internal jugular, by means of Mackenzie's tambour attachment to a Dudgeon's sphygmograph.



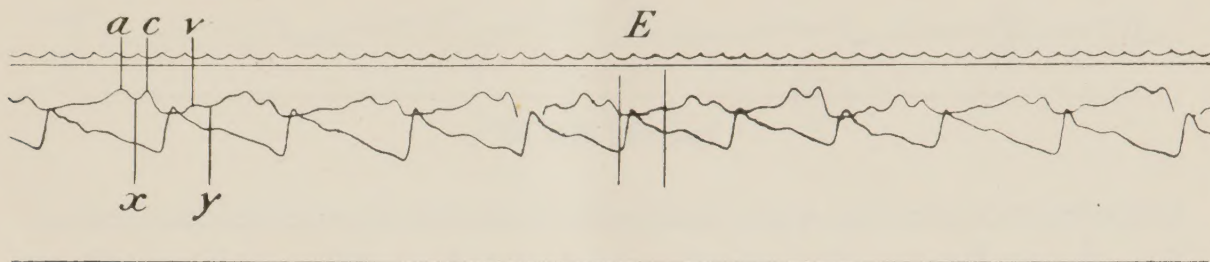
D, Presphygmic interval during which there is a forward movement of apex of heart while ventricle begins to contract. The pressure in the ventricle rapidly rising, the mitral valves close as soon as pressure in the ventricle exceeds that in the auricle. As soon as pressure in the ventricle exceeds that in the aorta, the semilunar valves open; this occurs at end of period (D).

E, Period of ventricular outflow.

F, Period of relaxation of ventricular muscle; a postsphygmic interval—the ventricular pressure is rapidly falling, and when below that in the auricles, the auriculo-ventricular valves open.

There are two rises in the auricular-pressure curve—a large one and a small one, with two falls. The first rise in pressure immediately precedes the rise in ventricular pressure due to systole of the auricle. When the auricle ceases to contract a fall (x) occurs, due to diastole of the auricle. The mitral valves are closed, and the blood pouring into the auricle from the veins, the pressure gradually rises, producing the second small wave in the curve. This wave is terminated by the opening of the auriculo-ventricular valves at the beginning of ventricular diastole—auricular pressure rises during the postsphygmic interval (F). When the pressure in the ventricles becomes lower than that in the auricles, the valves open, the blood passes through, auricular pressure is reduced, causing the second fall (y). Then the pressure slowly rises in both auricles and ventricles till it is suddenly increased by the next auricular systole.

Now take the following tracing of a venous pulse from one of my cases in a healthy man :—



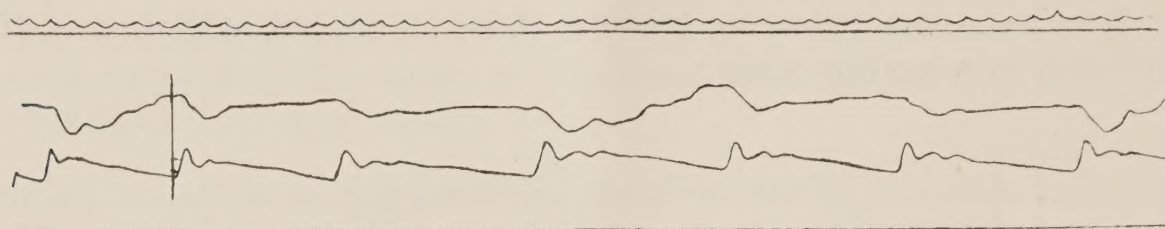
There is a large wave (A) preceding the period (E), which corresponds with the large wave in the diagram ; then comes a fall (x), due to the auricular diastole, which fall is interrupted by another rise (c), due to the carotid pulse, after which the fall continues, and is followed by a gradual rise (v), corresponding with small curve in diagram, continuing after (E) till auriculo-ventricular valves open, when a fall (y) occurs, interrupted by the next auricular systolic wave (A).

The wave (v) is due to increased pressure in the auricle, owing to blood flowing in from the veins ; and this curve becomes modified in cases of tricuspid incompetence, appearing earlier in the cardiac cycle the greater the incompetence ; for this reason Mackenzie calls it the ventricular wave, thus dividing a venous pulse into two types—auricular and ventricular. The latter being a morbid condition, and these present observations dealing only with normal pulses and hearts in which the valves are sound, no further reference will be made to it now, nor to the morbid states in which the auricular type of venous pulse occurs, and which are dealt with by Mackenzie.

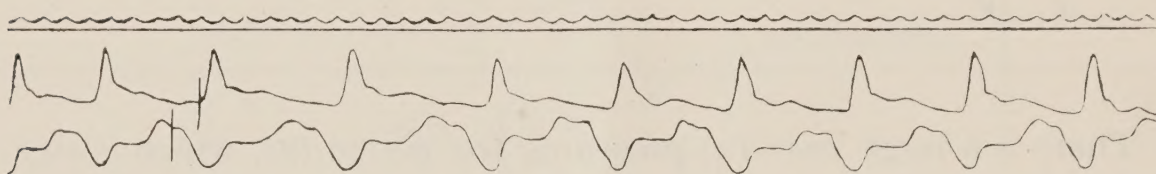
It has been supposed that the presence of a venous pulse in a healthy man is indicative of a weakness of the circulation, which would not stand a stress of exertion ; and that the heart would not respond so kindly to varying conditions as in the case of non-existence of venous pulse.

I think more extended observations on different classes of healthy people will not bear out that opinion. I have had a difficulty since commencing these observations in finding anyone without it, and, moreover, in a well-marked form ; that is, supposing the amplitude of the venous-pulse curves present any criterion, which is a point requiring further investigation. To illustrate this point I give two tracings (Tracings 25 and 26), showing a marked difference in the amplitude of the venous curves ; Tracing

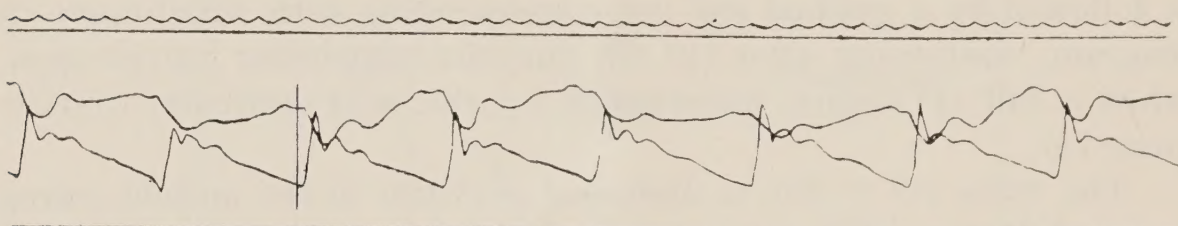
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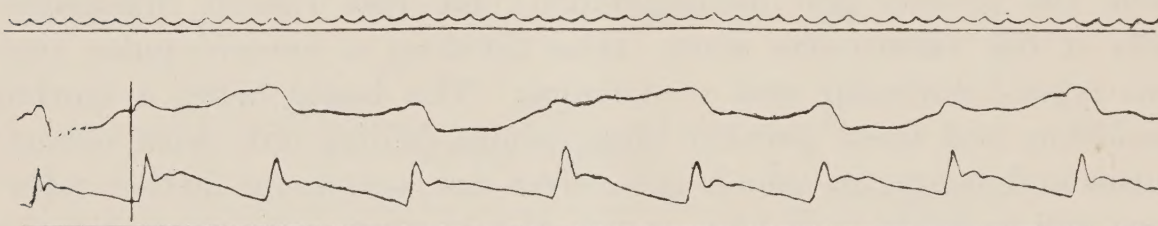
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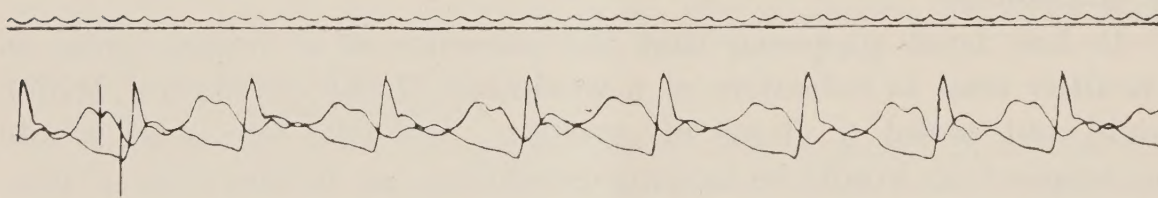
TRACING No. 26.



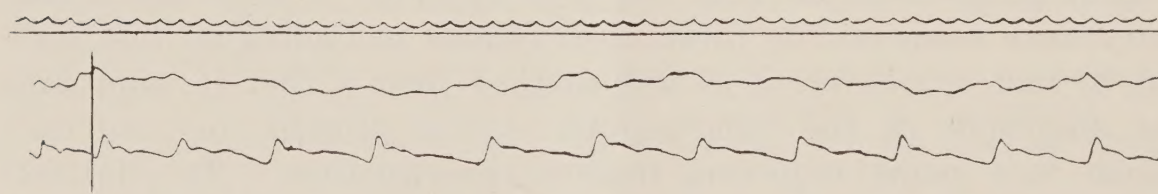
TRACING No. 27.



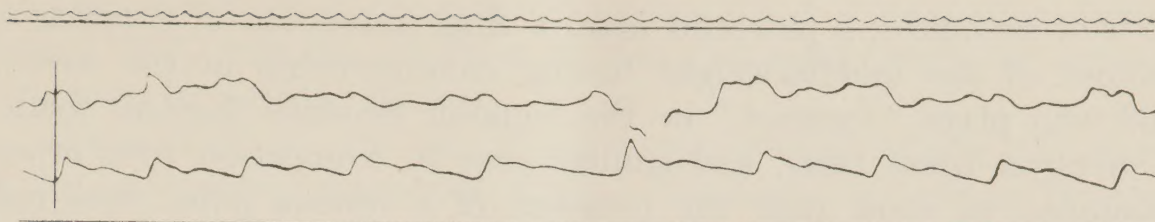
TRACING No. 28.



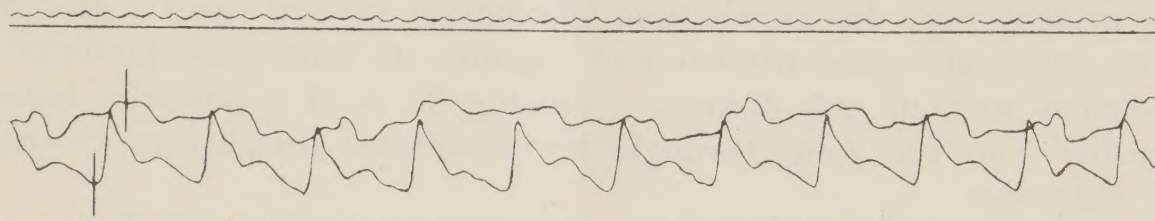
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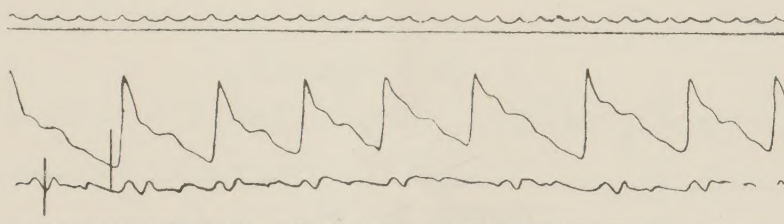
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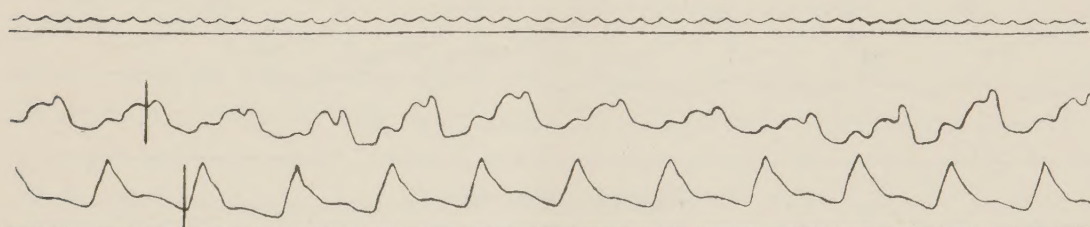
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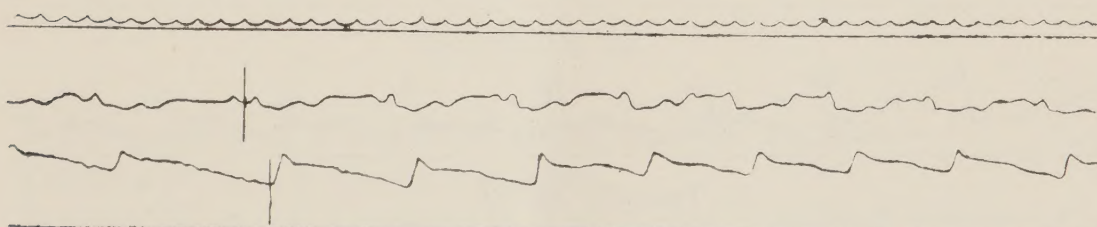
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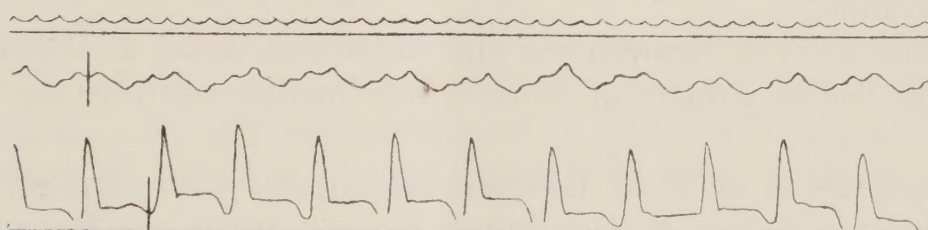
TRACING No. 33.



TRACING No. 34.



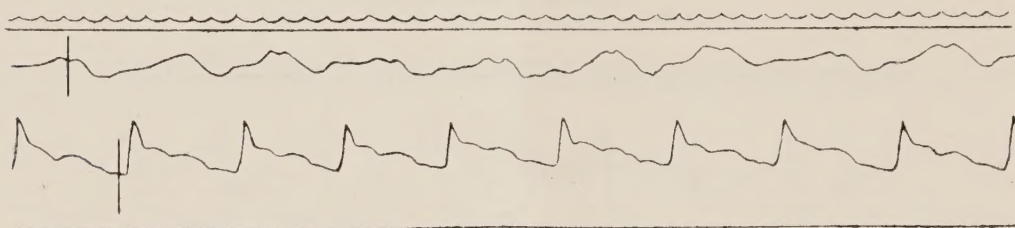
TRACING No. 35.



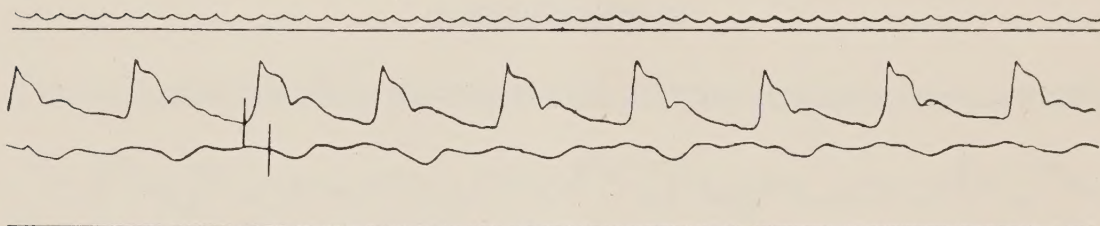
TRACING No. 36.

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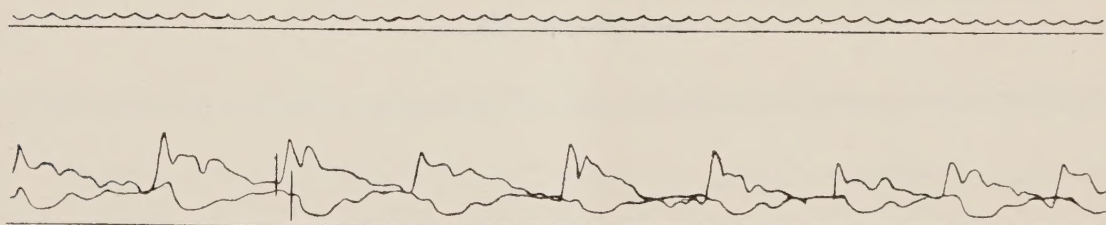
25 is of an officer, a powerful man, a Superintendent of Gymnasia, winner of the middle-weight boxing championship of the Army, and who plays "forward" in the London Scottish football team. I mention these facts, and similar ones in connection with other examples, to show that the presence of a venous pulse does not mean that the cardiac response is feeble, or that the subjects thereof are liable to breathlessness on exertion. On the contrary, it will be evident that the men whose tracings of venous pulse I give in this paper are good-winded and capable of hard and prolonged exertion without any distress. Tracing 26 is of a powerful bombardier who was going through the Gymnastic Instructors' Course at Aldershot.



TRACING NO. 37.



TRACING NO. 38.



TRACING NO. 39.

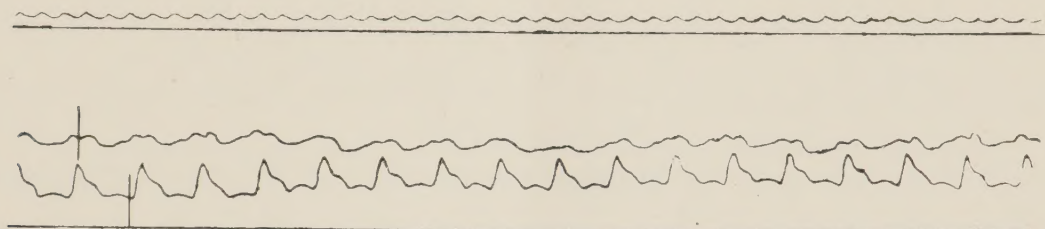
I will give examples of the tracings that I have obtained from various people.

Tracing 27 is of Lieutenant and Master-at-Arms J. Betts, Army Gymnastic Staff, winner of thirty-three medals at military tournaments.

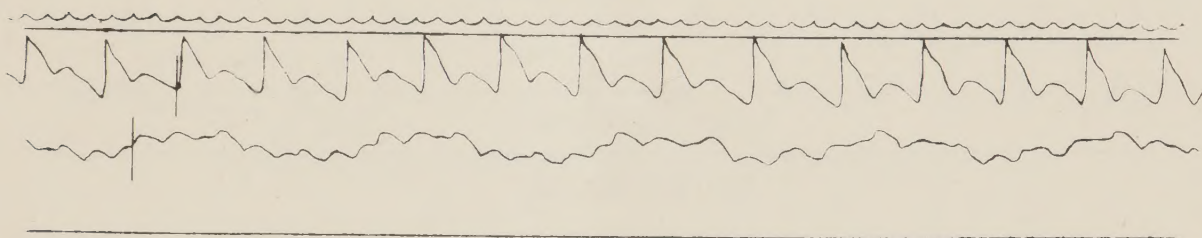
Tracing 28 is of Tom Burrows, champion club swinger of the world, and was taken at Edinburgh the day following his swinging clubs twelve hours a day for six consecutive days.

Tracing 29 is of Company-Sergeant-Major Dent, Army Gymnastic Staff, who, in addition to his gymnastic work, is boxing instructor to the 21st Lancers.

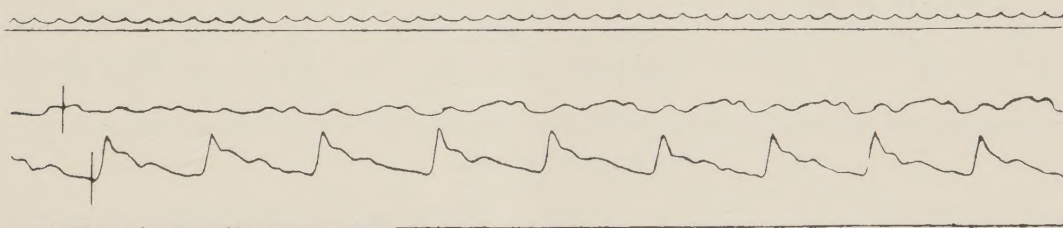
Tracings 30, 31, 32, are of non-commissioned officers who were in the Gymnastic Instructors' Class. The man from whom Tracing 30 was taken had previously served twelve years in a band, and it would be so easy to conclude that the fact of his playing wind instruments accounted for his venous pulse; but the other men had not so served.



TRACING No. 40.



TRACING No. 41.



TRACING No. 42.

Tracing 33 is of a recruit of three months' service.

Tracing 34 is of a medical student.

Tracing 35 is of Lieutenant Langkilde, a retired officer of the Danish Army, attached temporarily to the Aldershot Gymnasium as Instructor of Gymnastics.

Tracings 36, 37, are of two lady gymnasts trained on the Swedish system. These last three tracings show that the venous pulse has nothing to do with any particular kind of physical training.

Tracings 38, 39, are of two ladies who have had no physical training at all.

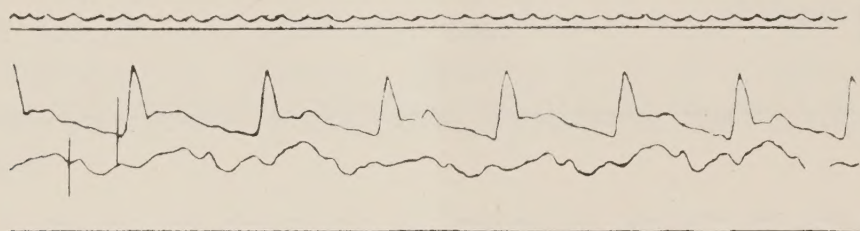
By kind permission of Sir Alfred Keogh, K.C.B., Director-General,

18 *Original Observations on Respiratory-Pulse Curves*

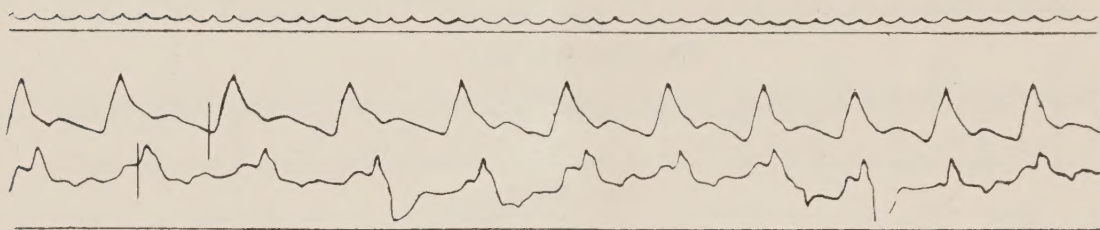
Army Medical Service, I went to Netley to make some observations on men invalided for "disordered action of the heart." All the men I saw at different visits had the auricular type of venous pulse, but I can only give a few examples.

Tracings 40, 41, 42, are such.

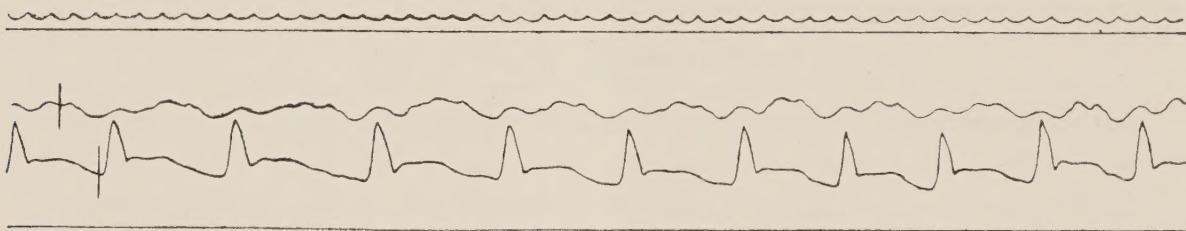
In order to further illustrate that the venous pulse, in itself, has no essential connection with the cardiac condition of these men, I



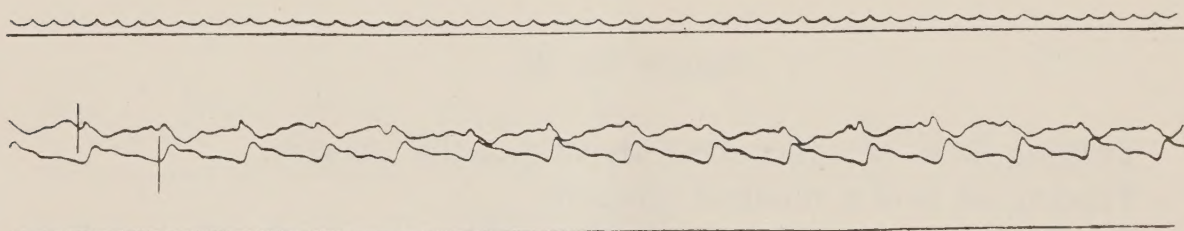
TRACING NO. 43.



TRACING NO. 44.



TRACING NO. 45.

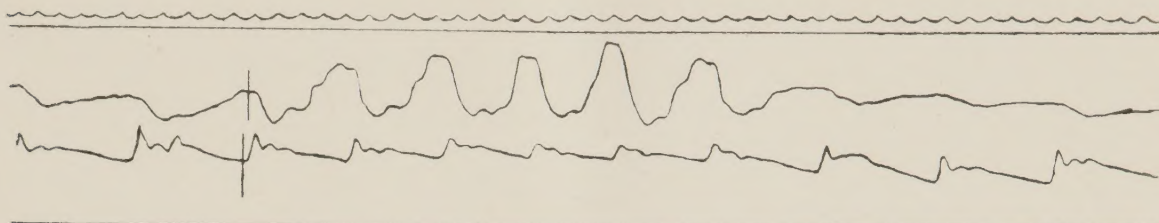


TRACING NO. 46.

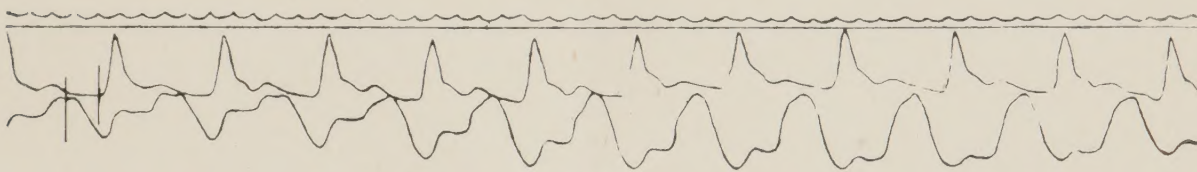
made observations on a medical officer doing duty in the Medical Division of the Hospital, on the Ward-master, and on patients in the Surgical Division, and they all had a venous pulse. Tracing 43 is of the medical officer mentioned. Also, by kind permission of the Director-General, I made observations on recruits for enlistment at St. George's Barracks, and it was exceptional to find one without a venous pulse. Tracings 44, 45, 46, are examples, the men being respectively a clerk, printer, and a motor driver.

I do not propose in this paper to refer to any changes in the venous-pulse curves, due to respiratory changes, in cases of disordered action of the heart, but to changes occurring in normal hearts during deep respiration. During a deep inspiration the amplitude of the venous curve becomes increased, at times greatly so.

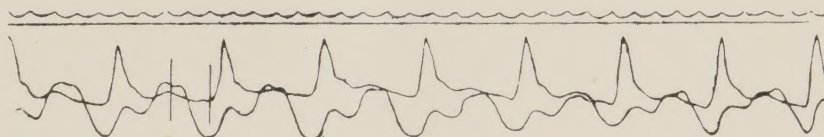
Tracings 47, 48, 49, 50, are illustrations. Tracing 48 shows the inspiratory curve, and 49 the expiratory curve of the same man.



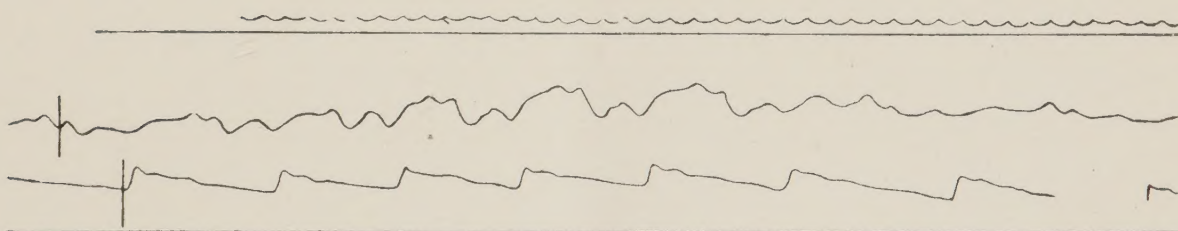
TRACING No. 47.



TRACING No. 48.



TRACING No. 49.



TRACING No. 50.

The significance of these changes is not clear and they require further study, and I defer consideration of them to a future occasion. The importance of ascertaining what happens in the healthy individual cannot be over-estimated. Conditions which are noticed first in an unhealthy man are liable and, indeed, almost certain to lead to faulty conclusions.

We hear a good deal nowadays about the respiratory treatment of chest diseases, when the effects of deep respiration require further study first on healthy people under natural conditions of work and play.

